Semester Two Examination, 2016

Question/Answer Booklet

CHEMISTRY

Student Name _____

Student Number: In figures | | | | | | | | |

In words _____

_____

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time for paper: three hours

Section	Marks
1	/25
	/50
2	/70
3	/80
total	/200
	%

Material required/recommended for this paper

To be provided by the supervisor
This Question/Answer booklet
Multiple-choice Answer sheet
Chemistry Data sheet

To be provided by the candidate
Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: up to three non-programmable calculators approved for use in the WACE examinations

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Multiple-choice	25	25	50	25	25
Section Two: Short answer	9	9	60	70	35
Section Three: Extended answer	5	5	70	80	40
				Total	100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2016*. Sitting this examination implies that you agree to abide by these rules.

2. Answer the questions according to the following instructions.

   Section One: Answer all questions on the separate Multiple-choice Answer Sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

   Sections Two and Three: Write your answers in this Question/Answer Booklet.

3. When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

4. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
   - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of question that you are continuing to answer at the top of the page.

6. The Chemistry Data Sheet is **not** handed in with your Question/Answer Booklet.

See next page

Section One: Multiple-choice **25% (25 marks)**

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 50 minutes.

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1. Which one of the following substances is the strongest acid?

   (a) HF
   (b) HNO_3
   (c) H_3PO_4
   (d) CH_3COOH

2. Which one of the following substances is the strongest reducing agent?

   (a) Au
   (b) Sr
   (c) FeI_3
   (d) H_2O_2

3. Consider the following system at equilibrium.

   $$Pb^{2+}(aq) + 2\,Br^{-}(aq) \rightleftharpoons PbBr_2(s) + \text{heat}$$

   Which one of the following changes would cause the concentration of lead(II) ions to be lowered (compared to the original concentration) once equilibrium is re-established?

   (a) Adding potassium iodide solution.
   (b) Stirring the mixture.
   (c) Warming the system.
   (d) Adding solid lead(II) bromide to the system.

4. Which one of the following 1.0 mol L^{-1} solutions will have the lowest pH?

   (a) sodium hydrogencarbonate
   (b) ammonium chloride
   (c) sodium ethanoate
   (d) sodium hydrogenphosphate

5. In which one of the following reactions is the carbon-containing species acting as a Brønsted-Lowry acid?

   (a) $NaHCO_3(s) + H^+(aq) \rightarrow Na^+(aq) + H_2O(\ell) + CO_2(g)$
   (b) $CO_2(g) + H_2O(\ell) \rightarrow H_2CO_3(aq)$
   (c) $H_2CO_3(aq) + NaOH \rightarrow NaHCO_3(aq) + H_2O(\ell)$
   (d) $CO_3^{2-}(aq) + Ca^{2+}(aq) \rightarrow CaCO_3(s)$

See next page

6. Which of the following combinations will form a buffer solution?

i. $NH_3(aq)$ / $NH_4C\ell(aq)$
ii. $NH_3(aq)$ / $HC\ell(aq)$
iii. $HC\ell(aq)$ / $NH_4C\ell(aq)$
iv. $H_2PO_4^-(aq)$ / $HPO_4^{2-}(aq)$
v. $H_2SO_4(aq)$ / $HSO_4^-(aq)$

(a) i and iv only
(b) i, iv and v only
(c) i, ii and iv only
(d) iv only

Question 7 and 8 relate the following information:

One of the processes involved in the acidification of the oceans caused by increasing carbon dioxide levels in the atmosphere is shown below:

$$HCO_3^-(aq) \rightleftharpoons CO_3^{2-}(aq) + H^+(aq)$$

7. Which one of the following statements is true?

(a) HCO_3^- is the conjugate base of the CO_3^{2-} ion.
(b) The HCO_3^- ion is the conjugate acid of the H^+ ion.
(c) HCO_3^- is the conjugate acid of the CO_3^{2-} ion.
(d) H^+ is the conjugate acid of the HCO_3^- ion.

8. Using this process and your knowledge of other chemical processes occurring in the ocean, which one of the following will reduce the acidity of the oceans?

(a) increased amount of sediments and shells that contain calcium carbonate.
(b) Increased concentration of carbon dioxide in the atmosphere
(c) Addition of more hydrogencarbonate ions into the ocean
(d) Increased extreme weather conditions causing wind and waves in the ocean

9. Water ionises according to the following reaction.

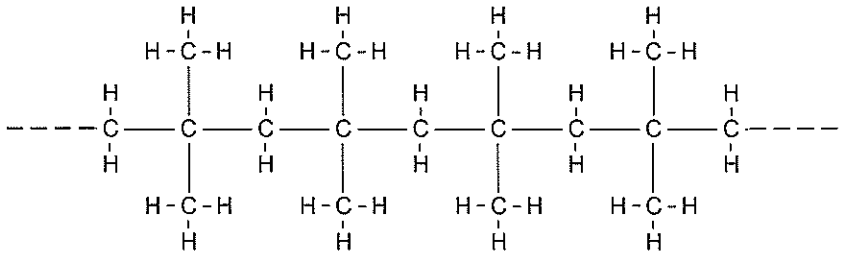
$$2\ H_2O(\ell) \rightleftharpoons OH^-(aq) + H_3O^+(aq)$$

At 25 °C the concentration of H^+ is 10^{-7} mol L^{-1} and the pH of pure water is 7.0. When the temperature is increased, the pH of water reduces. Which of the following statements below is correct?

(a) The forward reaction is endothermic.
(b) The concentration of $OH^-(aq)$ reduces, making the water more acidic.
(c) The water is no longer neutral, so the pH of water reduces.
(d) The concentration of the $H_3O^+(aq)$ reduces.

See next page

10. Consider the section of the polymer below.



Which one of the following is the correct name for the monomer used to synthesise this polymer?

(a) but-1-ene
(b) but-2-ene
(c) 2-methylpropene
(d) 2,2-dimethylethene

11. In which of the following processes is chlorine being oxidised?

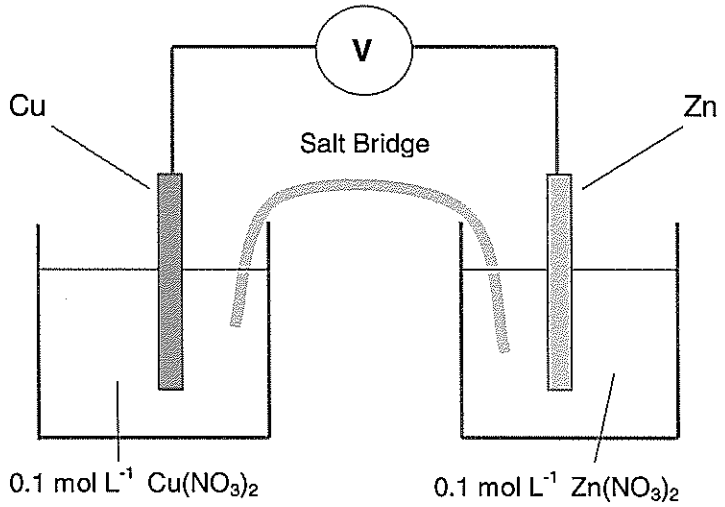
i. $PC\ell_3 + C\ell_2 \rightarrow PC\ell_5$
ii. $C\ell_2 + H_2O \rightarrow C\ell^- + HC\ell O + H^+$
iii. $2\,C\ell^- \rightarrow C\ell_2 + 2\,e^-$
iv. $HC\ell O_3 + H_2O_2 \rightarrow HC\ell O_4 + H_2O$

(a) i, ii and iv only
(b) ii, iii and iv only
(c) i, ii, iii and iv
(d) ii and iv only

See next page

The following diagram relates to questions 12 and 13

The following galvanic cell was set up.



12. Which one of the following is the purpose of the salt bridge?

(a) To increase the concentration of the ions in order to speed up the rate of the reaction.
(b) To allow the flow of electrons between the two electrodes.
(c) To complete the circuit to allow ions to flow between the two half-cells.
(d) To allow copper ions to flow to the zinc electrode

13. Which one of the following statements is **false**?

(a) The zinc electrode is the anode.
(b) The electrons in the wire move towards the copper electrode.
(c) The mass of the copper electrode will increase.
(d) Positive ions in the salt bridge move towards the lead electrode.

14. Which of the following reactions will occur spontaneously?

i. $2\ I^-(aq) + Br_2(aq) \rightarrow 2\ Br^-(aq) + I_2(aq)$
ii. $Cu(s) + 2\ HC\ell(aq) \rightarrow CuC\ell_2(aq) + H_2(aq)$
iii. $Sn(s) + Cd^{2+}(aq) \rightarrow Sn^{2+}(aq) + Cd(s)$
iv. $H_2O_2(aq) + Ni^{2+}(aq) \rightarrow O_2(g) + 2\ H^+(aq) + Ni(s)$

(a) i and iv only
(b) i only
(c) iii and iv
(d) iv only

See next page

Question 15, 16 and 17 relate to the following information

An aluminium-air battery is a fuel cell that involves aluminium reacting with oxygen in the air. The relevant half-equations are shown below.

$O_2(g) + 2\,H_2O(\ell) + 4\,e^- \rightleftharpoons 4\,OH^-(aq)$

$Al^{3+}(aq) + 3\,e^- \rightleftharpoons A\ell(s)$

15. This cell is described as a fuel cell because

(a) it is a sustainable power source that can be used to replace fossil fuels.
(b) both half-reactions are reversible so the cell can be recharged.
(c) it involves a gas as a reactant at one of the electrodes.
(d) it requires the reactants to be supplied to the cell during operation.

16. Which one of the following is the overall equation for the cell?

(a) $A\ell(s) + O_2(g) + 2\,H_2O(\ell) \rightarrow OH^-(aq) + A\ell^{3+}(aq)$
(b) $4\,A\ell^{3+}(aq) + 3\,O_2(g) + 6\,H_2O(\ell) \rightarrow 12\,OH^-(aq) + 4\,A\ell\,(s)$
(c) $A\ell^{3+}(aq) + O_2(g) + 2\,H_2O(\ell) \rightarrow 4\,OH^-(aq) + A\ell\,(s)$
(d) $4\,A\ell(s) + 3\,O_2(g) + 6\,H_2O(\ell) \rightarrow 12\,OH^-(aq) + 4\,A\ell^{3+}(aq)$

17. The theoretical voltage obtainable from this cell is

(a) 1.88 V.
(b) 2.08 V.
(c) 2.91 V.
(d) 5.52 V.

18. Substance **X** has an empirical formula of C_2H_4O. Which one of the following could **not** be substance **X**?

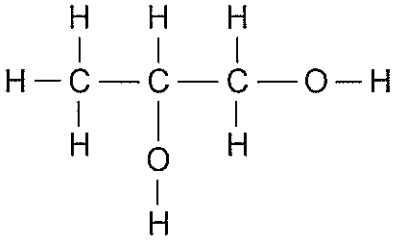
(a) butanoic acid
(b) ethyl ethanoate
(c) methyl methanoate
(d) methyl propanoate

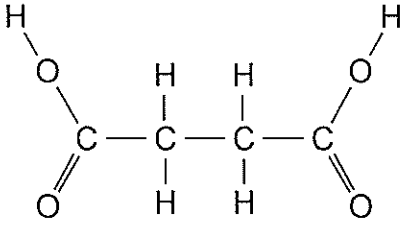
19. Which one of the following compounds will be readily oxidised to form a carboxylic acid?

(a) $CH_3CH_2C(OH)CH_3$
(b) $HOC(CH_3)_3$
(c) $CH_3CH_2COOCH_3$
(d) CH_3CH_2CHO

See next page

20. The following two substances were reacted together:





Which one of the following would be the type of product produced?

(a) a soap
(b) a fatty acid
(c) a polyester
(d) a protein

21. Which one of the following pairs of compounds would form methyl propanoate when warmed with concentrated sulfuric acid?

(a) CH_4 and CH_3CH_2COOH
(b) CH_3OH and $CH_3CH_2CH_2OH$
(c) CH_3OH and CH_3CH_2COOH
(d) $HCOOH$ and $CH_3CH_2CH_2OH$

22. Consider the dipeptide below.

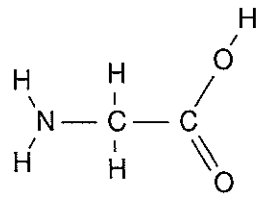
$HOOCCH(CH_3)NHCOCH(CH_2OH)NH_2$

Use your data sheet to identify which pair of amino acids below would form this dipeptide.

(a) alanine and valine
(b) valine and threonine
(c) glycine and serine
(d) serine and alanine

See next page

23. Consider the molecule below.



Which one of the following will this molecule **not** react with?

(a) dilute hydrochloric acid
(b) sodium hydrogencarbonate solution
(c) sodium chloride solution
(d) sodium hydroxide solution

24. Which one of the following are **not** bonds between sections of a protein that contribute to the tertiary structure of the protein?

(a) C=O bonds
(b) hydrogen bonds
(c) S–S bonds
(d) dispersion forces

25. Which one of the following is **not** an aim of the Protein Data Bank? (PDB)?

(a) Standardising the way protein structures are represented.
(b) Allowing companies to patent new discoveries of protein structures.
(c) Informing medical research such as development of the use of antibodies.
(d) Sharing knowledge of protein structures from scientists across the world.

End of Section One

See next page

Section Two: Short answer **35% (70 Marks)**

This section has **ten (10)** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

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Suggested working time: 60 minutes.

Question 26 **(6 marks)**

(a) Calculate the pH of a solution of 0.500 mol L^{-1} hydrochloric acid. (2 marks)

(b) A student was asked to dilute 50.0 mL of this solution to produce a solution of hydrochloric acid with a pH of 2.00. Calculate the volume of distilled water that she would she need to add. (3 marks)

Question 27 **(6 marks)**

Butan-2-ol can be oxidised with acidified potassium dichromate solution.

(a) Draw the structural formula and name the organic product formed. (2 marks)

Name _____

(b) (i) Draw and name an isomer of butan-2-ol that will react with potassium dichromate solution to produce a carboxylic acid. (2 marks)

Name _____

(ii) Write a balanced redox equation for this reaction. (2 marks)

Question 28 **(10 marks)**

Swimming pool maintenance uses sodium hypochlorite (NaClO), to control algae and bacteria. The swimming pool water can be considered as an equilibrium system as shown below, where hypochlorite ions are converted in to hypochlorous acid (HCℓO).

$$C\ell O^-(aq) + H_3O^+(aq) \rightleftharpoons HC\ell O(aq) + H_2O(\ell) + HEAT$$

For best results, the concentration of the hypochlorous acid should be kept above 1.00 ppm.

(a) Complete the table by using Le Châtelier's principle to predict, with reasoning, the effect of the following changes on the concentration of the hypochlorous acid (HCℓO) in the swimming pool. (6 marks)

Imposed change	**Prediction for any change to the concentration of HCℓO**	**Brief reasoning for prediction**
Increasing the pH of the pool		
Increasing the temperature of the pool		

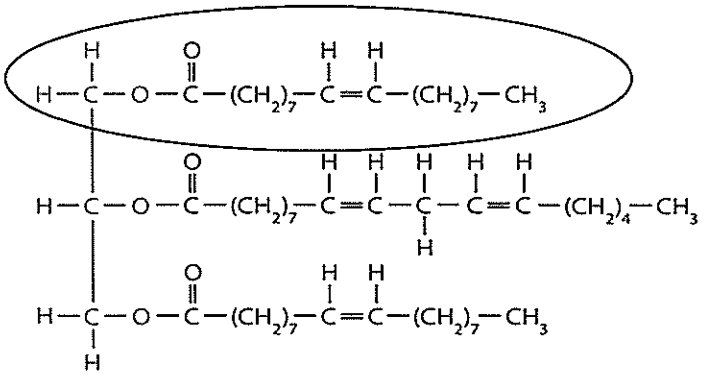
(b) (i) If the concentration is 1.50 ppm, calculate the mass of hypochlorous acid in a pool that has a capacity of 120 000 litres. (Assume 1.00 L of pool water has a mass of 1.00 kg) (1 mark)

(ii) Assuming 60% conversion of sodium hypochlorite to hypochlorous acid, calculate the mass of sodium hypochlorite that would be required provide this mass of hypochlorous acid. (3 marks)

See next page

Question 29 **(6 marks)**

Biodiesel is a fuel that can be synthesised from natural oils and fats. The molecule below is a triglyceride present in vegetable oil that can be used for this process.



Biodiesel can be synthesised using a base-catalysed reaction with methanol. The triglyceride breaks down into fatty acids and these undergo esterification with methanol to form methyl esters. The methyl esters are the main components of biodiesel.

(a) State why the compound above is described as an unsaturated oil. (1 mark)

_____

(b) Draw the structural formula of the methyl ester formed from the section of the molecule circled in the above diagram. (1 mark)

(c) Name a catalyst that can be used in this process. (1 mark)

_____

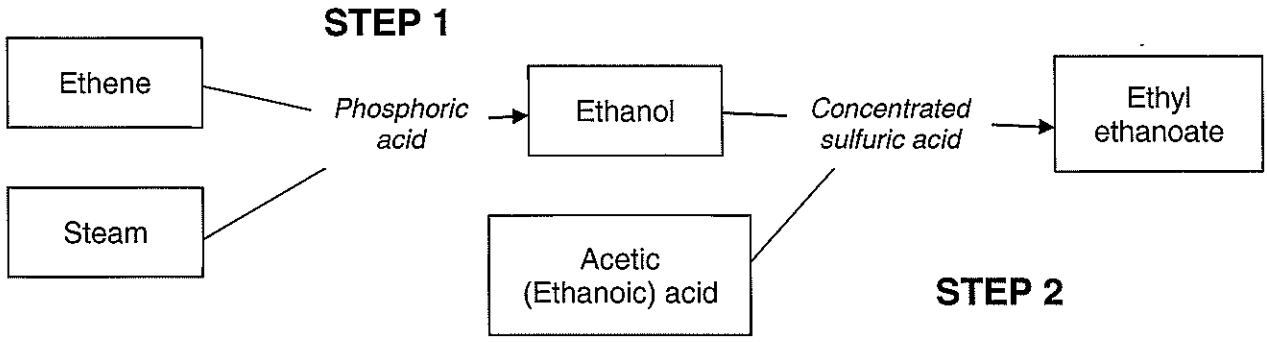
(d) As well as the methyl esters (the biodiesel), there is one other product of this reaction. Name and draw the structural formula of this product. (2 marks)

Name _____

See next page

Question 30 **(13 marks)**

The following reaction sequence can be used to synthesise ethyl ethanoate.



(a) Phosphoric acid and sulfuric acid act as catalysts in this reaction sequence. Explain, using collision theory, how a catalyst speeds up a chemical reaction. (2 marks)

(b) Consider Step 1 and Step 2 in this reaction sequence.

(i) Write the equation for Step 1 and explain why it is described as an addition reaction. (2 marks)

(ii) Write the equation for Step 2 and explain why it is described as a condensation reaction. (2 marks)

See next page

(c) In Step 1, 458 kg of ethene was reacted with excess steam and 48.5 kg of ethanol was produced. Calculate the percentage yield of this reaction. (4 marks)

(d) Ethanol can also be produced using fermentation. Biomass provides glucose ($C_6H_{12}O_6$) which is fermented, producing ethanol and carbon dioxide as a by-product.

(i) Write an equation showing the conversion of glucose to ethanol. (1 mark)

(ii) In this process, the reaction is catalysed by enzymes. Describe two characteristics of enzymes that make them different from catalysts such as phosphoric acid and sulfuric acid. (2 marks)

See next page

Question 31 **(9 marks)**

Sodium stearate ($CH_3(CH_2)_{16}COONa$) is a soap.

(a) Using a diagram, and your knowledge of intermolecular forces, explain how the polarity of the stearate ion enables the soap to remove grease from a surface. (4 marks)

(b) In hard water, soaps can form a precipitate of calcium stearate (scum).

(i) Write an ionic equation, including state symbols, showing this process. (3 marks)

(ii) Describe two problems caused by the formation of scum. (2 marks)

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See next page

Question 32 **(7 marks)**

A group of students was investigating the equilibrium between dichromate and chromate ions. The equation for the system is shown below:

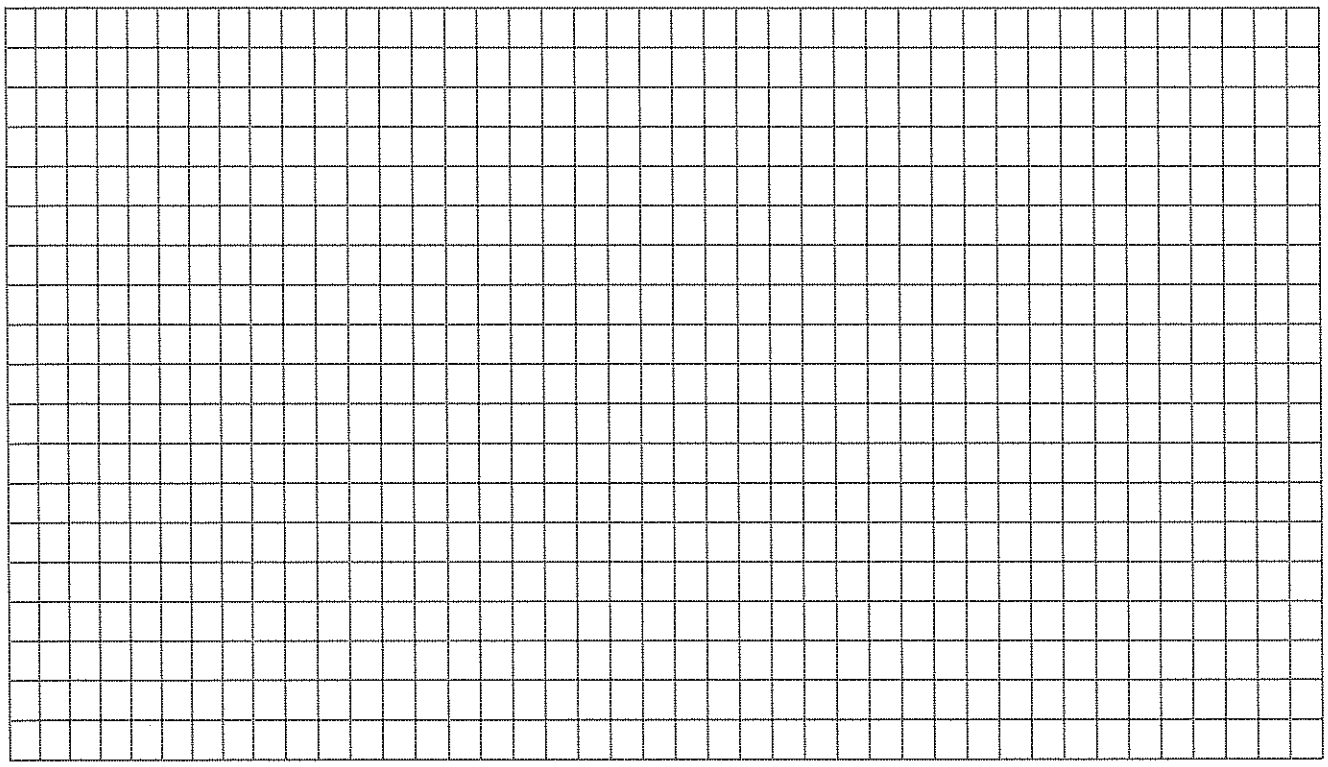
$2\ CrO_4^{2-}(aq) + 2\ H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(\ell)$

They started with 50.0 mL of a solution of 0.10 mol L^{-1} potassium chromate, and gradually added hydrochloric acid to the solution. They recorded the colour of the solution and the pH using a pH meter. Their results are shown below.

Table 1. Colour of a solution of potassium chromate on addition of 1.0 mol L^{-1} hydrochloric acid

Measurement	Volume of HCℓ(aq) (mL)	pH	Colour of solution
1	0.0	10	green/yellow
2	0.5	9.9	green/yellow
3	1.0	9.8	green/yellow
4	1.5	9.7	green/yellow
5	2.0	7.3	yellow
6	2.5	6.5	orange
7	3.0	4.5	orange
8	3.5	3.4	orange
9	4.0	2.1	orange

(a) Plot a graph on the grid below showing the variation of pH against volume of hydrochloric acid added. *(a spare grid is provided at the end of the questions if required)* (4 marks)



See next page

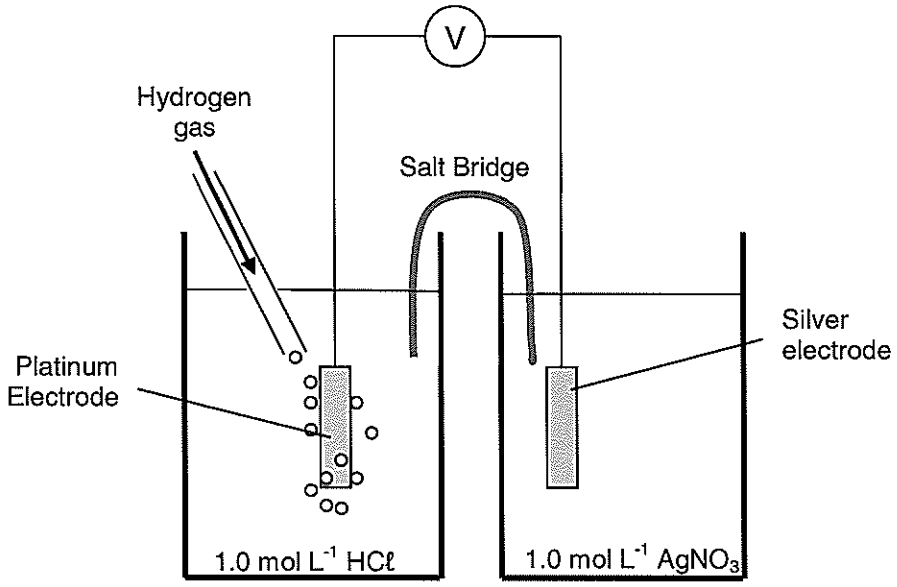
(b) Suggest why there was no significant change in pH for the first four measurements. (1 mark)

(c) Based on these results, the students concluded that potassium chromate could be used as an indicator in an acid-base titration. Evaluate this conclusion. (2 marks)

See next page

Question 33 **(8 marks)**

Below is a representation of an electrochemical cell used to measure the standard reduction potential for the Ag/Ag^+ half-cell.



(a) Give the half-equation for the reactions occurring at the anode and cathode and write an overall redox equation for the reaction occurring in the cell. (3 marks)

Anode half-equation:
Cathode half-equation:
Overall equation:

(b) Use an arrow to show the movement of electrons in the external circuit on the diagram above. (1 mark)

(c) Explain why 1.0 mol L^{-1} sulfuric acid is not used as the electrolyte in the hydrogen half-cell. (2 marks)

(d) Apart from the concentrations of the solutions, state two other conditions required to achieve an accurate measurement of the standard reduction potential for the Ag^+/Ag half-cell. (2 marks)

See next page

Question 34 **(7 marks)**

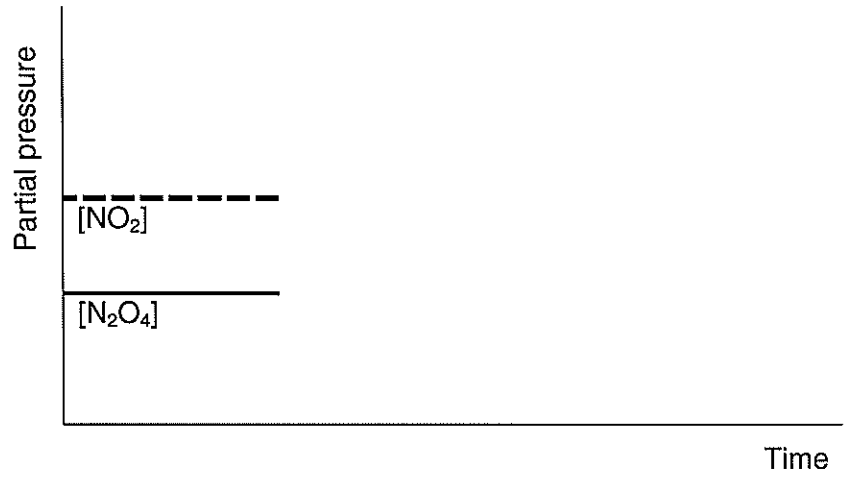
A student was investigating the equilibrium between the brown gas, nitrogen dioxide (NO_2) and the colourless gas dinitrogen tetroxide (N_2O_4). The gases were contained in a syringe. The syringe was suddenly squeezed to reduce the volume of the system. The temperature of the system was not changed. The equation for the equilibrium is shown below.

$$2\ NO_2(g) \rightleftharpoons N_2O_4(g) \quad \Delta H = -57.2\ kJ\ mol^{-1}$$

(a) Write the equilibrium constant expression for this reaction. (1 mark)

K =

(b) Complete the following graph to show what happens to the partial pressures of nitrogen dioxide and dinitrogen tetroxide as the syringe is squeezed and the system responds to the change by re-establishing equilibrium. (3 marks)



(c) Explain, with reference to reaction rates and collision theory, the shape of the graph drawn in part (b). (3 marks)

End of Section Two

See next page

Section Three: Extended answer **40% (80 marks)**

This section contains **five (5)** questions. You must answer **all** questions. Write your answers in the spaces provided.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures.

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Suggested working time: 70 minutes.

Question 35 **(22 marks)**

Aspartic acid ($C_4H_7O_4N$) is a diprotic α-amino acid. Aspartic acid has solubility of 4.5 g L^{-1} at 25 °C and a K_a value of 1.26×10^{-4}. Aspartic acid increases resistance to fatigue and is often found in food supplements, especially those used by athletes and body builders.

A chemist was asked to analyse the contents of a food supplement to check the manufacturer's claims that it contained 97.0% aspartic acid by mass. To check this claim, the following experiment was carried out. (It can be assumed that aspartic acid is the only active ingredient in the supplement)

1. 1.546 g of the supplement powder was weighed and dissolved in warmed distilled water in a beaker.
2. The solution was transferred to a 500.0 mL volumetric flask and was made up to the mark with distilled water.
3. 25.00 mL aliquots of the resulting solution were titrated, using phenolphthalein indicator, against 0.0570 mol L^{-1} sodium hydroxide solution.

See next page

The results obtained are shown below.

Burette readings (mL)	Titrations			
	1	2	3	4
Final volume	20.30	40.05	19.80	39.50
Initial volume	0.00	20.30	0.00	19.80
Titration volume (titre)				

(a) Calculate the percentage purity of the supplement. (7 marks)

See next page

(b) Consider the method used in this experiment.

(i) In Step 1, suggest a reason why the distilled water was warmed. (1 mark)

(ii) In Step 2, the solution was transferred from a beaker into the volumetric flask. Explain why this process could be a source of systematic error. (2 marks)

(iii) Phenolphthalein changes colour at between pH 9 –10. Methyl orange changes colour at between pH 4 –5. In Step 3, predict and explain the effect on the final result if methyl orange was used as the indicator instead of phenolphthalein. (3 marks)

See next page

(c) (i) Due to the low solubility of the aspartic acid, it was suggested to the students that they use a 'back titration'. This would require the addition of a known amount of sodium hydroxide (in excess) to the aspartic acid and the titration of the unreacted hydroxide against a standard solution of acid.

Sodium hydroxide solution with a concentration of 0.978 mol L^{-1} is used and there is a standard solution of 0.100 mol L^{-1} hydrochloric acid available.

There are three pipettes to choose from (20.00 mL, 25.00 mL or 50.00 mL) for adding sodium hydroxide solution to the 1.546 g of the supplement powder.

Calculate which volume pipette the student should use to add the sodium hydroxide in order to get a titration volume (titre) of approximately 20 mL of the hydrochloric acid. (7 marks)

(ii) Explain why having a titre of less than 20 mL could increase the random error in this experiment. (2 marks)

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Question 36 **(11 marks)**

Proteins comprise up to 2000 α-amino acid molecules joined to form a polymer. The structure of 20 commonly occurring α-amino acids are given on your data sheet. The structure of proteins can be defined on a series of levels.

Compare the primary, secondary and tertiary structure of proteins by

(a) drawing the primary structure of the section of a protein represented by:

– Gly – Ala – Val –

(show all atoms in your diagram)

(b) using a diagram to show how hydrogen bonding occurs between two parts of a protein molecule which contributes to the **secondary structure** of a protein.

(c) using diagrams to predict and explain the type of bonding which contribute to the **tertiary structure** of the protein that would be formed between the side groups of the following pairs of amino acids in proteins.

- glutamic acid (Glu) and lysine (Lys)
- leucine (Leu) and isoleucine (Ile)
- two cysteine (Cys) molecules

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Question 37 **(19 marks)**

In Mount Isa, Queensland, one of the world's most productive mines produces lead, silver, zinc and copper ore. One of the minerals extracted at Mount Isa is chalcopyrite ($CuFeS_2$), and the reaction used to process this compound is shown below.

Reaction 1 $2\ CuFeS_2 + 3\ O_2 \rightarrow 2\ FeO + 2\ CuS + 2\ SO_2$

The copper-containing compound is then reacted with more oxygen as shown below:

Reaction 2 $CuS + O_2 \rightarrow Cu + SO_2$

There is also a sulfuric acid plant at Mount Isa, which collects, then cleans sulphur dioxide before converting it to sulfuric acid via the Contact process.

The Contact process includes the following exothermic reaction, which has a yield of 87.0%

Reaction 3 $2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$

The conditions used in Reaction 3 are a moderately high temperature of 450 °C, a pressure close to normal atmospheric temperature and a catalyst of vanadium(V) oxide.

The sulfur trioxide produced is then added to sulfuric acid to produce oleum, which reacts with water to produce sulfuric acid with a purity of 98%. This two-stage process which can be summarized as:

Reaction 4 $SO_3(g) + H_2O(\ell) \rightarrow H_2SO_4(\ell)$

(a) Assuming Reaction 1 and 2 are 100% efficient; calculate the mass of chalcopyrite required to produce 1.00 tonne of copper metal. (1.00 tonne = 1.00×10^6 g) (3 marks)

(b) Calculate the total number of moles of sulfur dioxide generated in the production of 1.00 tonne of copper. (2 marks)

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(c) In 2012 the Mount Isa mine was producing 280 tonnes of copper per day from chalcopyrite and the sulfuric acid plant had to be closed down for maintenance and repair. Sulfur dioxide that would have been processed by the sulfuric acid plant was released to the atmosphere. Calculate the mass of sulfur dioxide in tonnes, released to the atmosphere each day during this time. (2 marks)

(d) Calculate the mass of sulfur trioxide produced in Reaction 3 from 1.00 tonne of sulfur dioxide. (3 marks)

(e) The sulfuric acid plant at Mount Isa has the capacity to produce 3,700 tonnes of 98% sulfuric acid per day. At full capacity, calculate the volume of water required by the sulfuric acid plant each day. (1.00 kg of water has a volume of 1.00 L) (5 marks)

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(h) Explain, in terms of green chemistry,

(i) two benefits of the two plants operating together at the Mount Isa site. (2 marks)

(ii) why a catalyst, and not a higher temperature, is used in Reaction 3. (2 marks)

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Question 38 **(10 marks)**

Banana oil contains an ester which gives the oil its distinctive odour. A series of experiments were carried out to determine the formula of this ester, which was known to contain just carbon, hydrogen and oxygen.

1.51 g of the ester was combusted in excess oxygen and 3.57 g of carbon dioxide was produced.

A second sample weighing 2.11 g was combusted in excess oxygen and 2.04 g of water was produced.

(a) Calculate the empirical formula of the ester. (6 marks)

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A third sample weighing 0.401 g was vaporised and the gas produced was found to occupy a volume of 162 mL at 150 °C at 67.0 kPa.

(b) From this information, prove that the empirical formula of the ester is the same as the molecular formula. (3 marks)

(c) (This ester can be synthesised from an alcohol and a carboxylic acid. The alcohol required is 3-methylbutan-1-ol.

Draw the structural formula of the ester present in banana oil. (1 mark)

Question 39 **(18 marks)**

Oxidation involves the loss of electrons from a chemical species. Redox reactions involve the oxidation of one species and reduction of another species. Electrochemical cells, including galvanic and electrolytic cells, consist of oxidation and reduction half-reactions connected via an external circuit.

The following situations all involve a species being oxidised.

1. An iron nail slowly dissolving in a solution of copper(II) sulfate.
2. The dissolving of a piece of impure copper at the anode of a cell used to purify copper.
3. The reaction occurring at the anode of a galvanic cell made up of zinc metal in aqueous zinc nitrate and tin metal in aqueous tin(II) nitrate.

Using the following headings and using only examples from the above situations to illustrate your explanations, and including equations and diagrams where appropriate, compare

(i) spontaneous and non-spontaneous reactions. (6 marks)

(ii) galvanic cells and electrolytic cells. (6 marks)

(iii) weak and strong oxidising agents. (6 marks)

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End of questions

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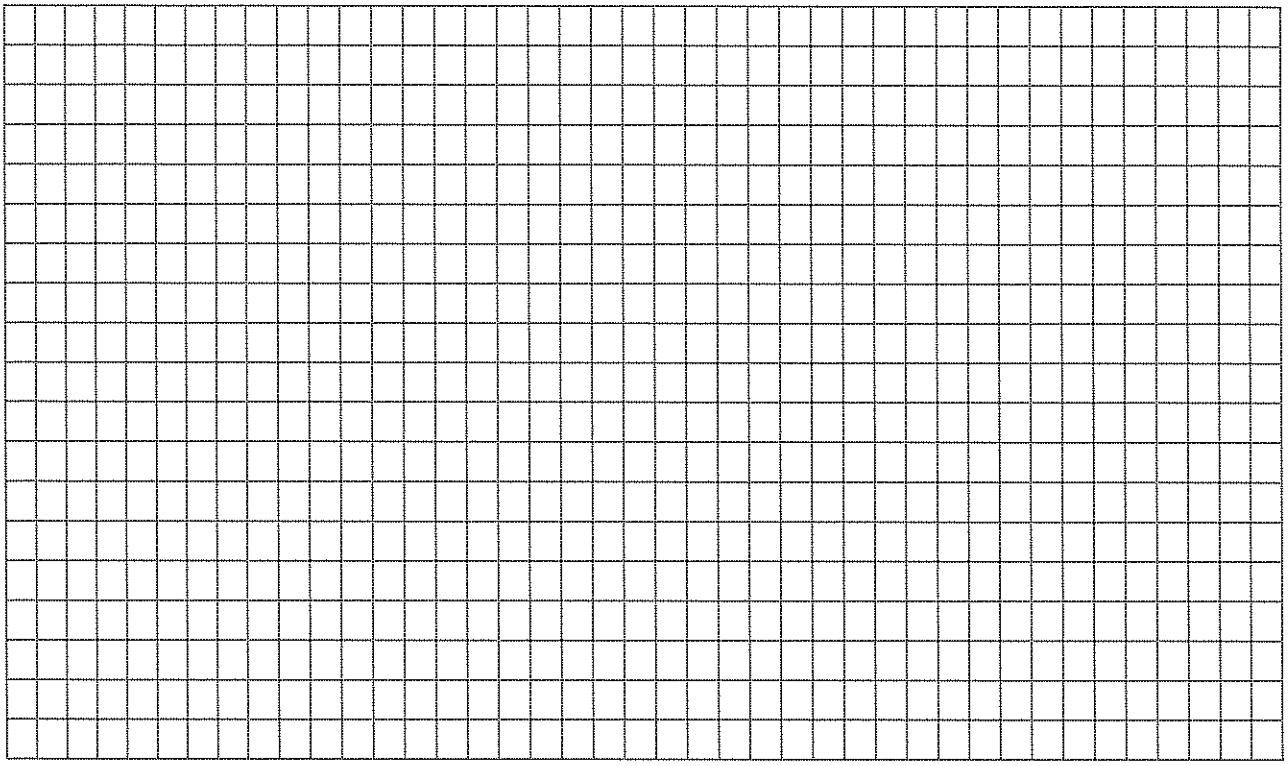

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